Chapter

8

8. Navigation and Position Determination

Navigation is the process of continuously determining your position so you can get from one place to a desired location. By correctly using various navigational techniques, you can efficiently proceed from one point to the next while keeping off-course maneuvering, elapsed time, and fuel consumption to a minimum. Navigation and position determination (situational awareness) is critical to the CAP mission. It doesn't do any good to go searching if you get lost and become a search object yourself. This chapter will cover the basic tools of navigation, navigational techniques, and the use of radio aids and instruments.

OBJECTIVES:

1. Define the following navigational terms: {S; 8.1}
   a. Course, heading and ground track.
   b. Drift and drift correction.
   c. Nautical mile and knot.
   d. Latitude and longitude.
2. Given a map or sectional: identify an object given its latitude and longitude; and given a position determine its latitude and longitude. {S; 8.2.3}
3. Discuss considerations for operating near controlled airports, and identify them on a sectional. {O; 8.4}
4. Discuss the following special use airspaces, and identify them on a sectional: {O; 8.4.1 & 8.4.2}
   a. Prohibited and restricted areas.
   b. Military operating areas and training routes.
5. Discuss the uses and limitations of the following navaids: {O; 8.5}
   a. ADF {8.5.1}
   b. VOR {8.5.2}
   c. DME {8.5.3}
   d. GPS {8.5.5}

6. Given a sectional chart, locate and discuss the following: {S; 8.6}
    a. Physical features such as topographical details.
    b. Towns and cities.
    c. Highways and roads
    d. Towers; determine height both in MSL and AGL.
    e. Airways and radio aids to navigation.
    f. Airports and airport data.
7. Given a sectional chart, discuss the information found in the legend. {S; 8.6}
8. Given a sectional chart, locate Maximum Elevation Figures and state their meaning. {S; 8.7.2}
9. Given a sectional chart, a plotter, and two points on the chart: {S; 8.8}
    a. Determine the heading.
    b. Determine the distance between the points (nautical and statute miles).
10. Given a sectional chart, a plotter, and two airports: {O; 8.8.1}
    a. Plot the course.
    b. Identify check points along the route.
    c. Calculate how long it should take to get from one airport to the other, flying at 100 knots and no wind.
11. State the size of a full and a one-quarter standardized grid. {S; 8.9.1}
12. Given Attachment E of the *U.S. National SAR Supplement to the International Aeronautical and Maritime SAR Manual*, grid a sectional. {O & P; 8.9.1 and Attachment 1}
13. Given coordinates and a sectional, use the *Standardized Latitude and Longitude Grid System* to draw a search grid. {O & P; 8.10}

8.1 Navigation Terms

In order to effectively communicate with the pilot and ground teams, the scanner and observer must have a clear understanding of various terms that are used frequently when flying aboard CAP aircraft. These are not peculiar to search and rescue, but are used by all civilian and military aviators.

Course - The planned or actual path of the aircraft over the ground. The course can be either *true course* or *magnetic course* depending upon whether it is measured by referencing true north or magnetic north. The magnetic north pole is *not* located at the true North Pole on the actual axis of rotation, so there is usually a difference between true course and magnetic course.

Pilots measure true course against a meridian of longitude at the midpoint of each leg, and all of these meridians point to the true North Pole. However, since the aircraft compass can only point at the magnetic north pole you must apply *magnetic variation* to the true course to determine the magnetic direction you must fly in order to follow the true course. East magnetic variation is subtracted from measured true courses and west variation is added.

You can find magnetic variation factors in several places, and you will learn more about this in the section concerning charts. Magnetic variation factors also take into account abnormalities in the earth's magnetic field due to the uneven distribution of iron ore and other minerals.

Heading - The direction the aircraft is *physically* pointed. An airplane's track over the ground doesn't always correspond with the direction they're pointed. This is due to the effect of wind. True heading is based on the true North Pole, and magnetic heading is based on the magnetic north pole. Most airplane compasses can only reference magnetic north without resorting to advanced techniques or equipment, so headings are almost always magnetic.

Drift, or Drift Effect - The effect the wind has on an aircraft. The air mass an aircraft flies through rarely stands still. If you try to cross a river in a boat by pointing the bow straight across the river and maintaining that heading all the way across, you will impact the river bank downstream of your initial aim point due to the effect of the river current. In an aircraft, any wind that is not from directly in the front or rear of the aircraft has a similar affect. The motion of the airplane relative to the surface of the earth depends upon the fact that the airplane is moving relative to the air mass and the air mass is moving relative to the surface of the earth. Adding these two gives the resultant vector of the airplane moving relative to the surface of the earth. The angle between the heading and the actual ground track is called the drift angle.

Drift Correction - A number of degrees added to or subtracted from the aircraft heading intended to negate drift or drift effect. In the rowboat example, if you had aimed at a point upstream of the intended destination, you would have crossed in a straighter line. The angle between the intended impact point and the upstream aim point is analogous to drift correction.

Ground Track - The actual path of the airplane over the surface of the earth.

Nautical mile (nm) - Distances in air navigation are usually measured in *nautical miles,* not statute miles. A nautical mile is about 6076 feet (sometimes rounded to 6080 feet), compared to 5280 feet for the statute mile. Most experienced aviators simply refer to a nautical mile as a mile. *Aircrews should remain aware of this difference when communicating with ground search teams* *because most ground or surface distances are measured using statute miles or kilometers*. To convert nautical miles into statute miles, multiply nautical miles by 1.15. To find kilometers, multiply nautical miles by 1.85. Also, one nautical mile is equal to one minute of latitude: this provides a convenient scale for measuring distances on any chart. Nautical miles are abbreviated "nm".

Knots (kts) - The number of nautical miles flown in one hour. Almost all airspeed indicators measure speed in terms of knots, not miles per hour. One hundred knots indicates that the aircraft would fly one hundred nautical miles in one hour in a no wind condition. Some aircraft have airspeed indicators that measure speed in statute miles per hour, and the observer should be alert to this when planning. Knots can be used to measure both *airspeed* and *ground speed*. The air mass rarely stands still, and any headwind or tailwind will result in a difference between the aircraft's airspeed and ground speed. If you fly eastward at 100 knots airspeed, with the wind blowing from the west at 15 knots, your speed over the ground would be 115 knots. If you fly westbound into the wind, your speed over the ground drops to 85 knots.

8.2 Latitude and longitude

In order to successfully navigate any vessel, the navigator must first have an understanding of the basic tools of navigation. Navigation begins with is a common reference system or imaginary grid "drawn" on the earth's surface by *parallels of latitude* and *meridians of longitude.* This system is based on an assumption that the earth is spherical. In reality, it's slightly irregular, but the irregularities are small, and errors caused by the irregularities can be easily corrected. The numbers representing a position in terms of latitude and longitude are known as the coordinates of that position. Each is measured in degrees, and each degree is divided into 60 smaller increments called minutes. Each minute may be further divided into 60 seconds, or tenths and hundredths of minutes.

8.2.1 Latitude

Latitude is the angular distance of a place north or south from the equator. The equator is a great circle midway between the poles. Parallel with the equator are lines of latitude. Each of these parallel lines is a small circle, and each has a definitive location. The location of the latitude is determined by figuring the angle at the center of the earth between the latitude and the equator.

The equator is latitude 0º, and the poles are located at 90º latitude. Since there are two latitudes with the same number (two 45º latitudes, two 30º, etc.) the letter designators N and S are used to show which latitude is meant. The North Pole is 90º north of the equator and the South Pole is 90º south of the equator. Thus the areas between the poles and the equator are known as the northern and southern hemispheres.

8.2.2 Longitude

We have seen how the north-south measurement of positions is figured. With only latitude, it is still impossible to locate a point. This difficulty is resolved by use of longitude, which indicates east-west location.

There is no natural starting point for numbering longitude. Therefore the solution is to select an arbitrary starting point. When the sailors of England began to make charts, they chose the meridian through their principal observatory in Greenwich, England, as the zero line. Most countries of the world have now adopted this line. The Greenwich meridian is sometimes called the first, or prime meridian (actually, the zero meridian).

Longitude is counted east and west from this meridian through 180º. Thus the Greenwich Meridian is zero degrees longitude on one side of the earth, and after crossing the poles it becomes the 180th meridian (180º east or west of the 0-degree meridian). Therefore we have all longitudes designated either west or east, for example, E 140º or W 90º. The E and W designations define the eastern and western hemispheres.

8.2.3 Position location

Refer to Figure 8-1. *By convention, latitude is always stated first*.

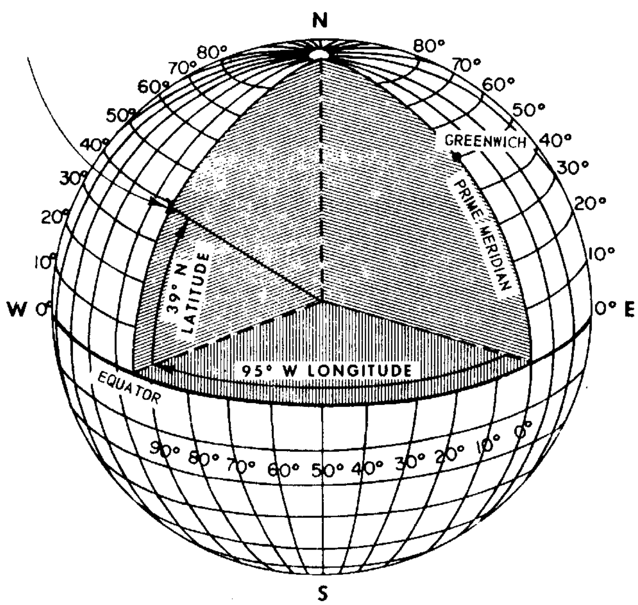

Figure 8-1

This system is used to precisely locate any point on the earth's surface. When identifying a location by its position within this latitude-longitude matrix, you identify the position's *coordinates,* always indicating latitude first and then longitude. For example, the coordinates N 39° 04.1', W 95° 37.3' are read as "north thirty-nine degrees, four point one minutes latitude, west ninety-five degrees, thirty-seven point three minutes longitude." If you locate these coordinates on *any* appropriate aeronautical chart of North America, you will *always* find Philip Billard Municipal Airport in Topeka, Kansas.

It is important to remember that in the northern hemisphere, latitude numbers increase as you proceed from south to north, and decrease as you move north to south. In the western hemisphere, longitude numbers increase when proceeding east to west, and decrease when moving west to east. Since the GPS receiver displays latitude and longitude with a great degree of accurately, pilots can use this tool to navigate and to fly very precise search patterns.

8.3 Magnetic variation

Variation is the angle between true north and magnetic north. It is expressed as east variation or west variation depending upon whether magnetic north (MN) is to the east or west of true north (TN), respectively. The north magnetic pole is located close to latitude N 71º, longitude W 96º - about 1,300 miles from the geographic or true north pole. If the earth were uniformly magnetized, the compass needle would point toward the magnetic pole, in which case the variation between true north and magnetic north could be measured at any intersection of the meridians.

Actually, the earth is not uniformly magnetized. In the United States the needle usually points in the general direction of the magnetic pole but it may vary in certain geographical localities by many degrees. Consequently, the National Ocean Survey has carefully determined the exact amount of variation at thousands of selected locations in the United States. The amount and the direction of variation, which change slightly from time to time, are shown on most aeronautical charts as broken red lines, called isogonic lines, which connect points of equal magnetic variation. The line connecting points at which there is no variation between true north and magnetic north is the agonic line.

8.4 Airspace

For traffic management purposes, the FAA has designated that all airspace within the United States falls into one of six different class designations (A, B, C, D, E, and G). Flight within each class requires certain communication, equipment, pilot experience, and, under some circumstances, weather requirements. Specific requirements for each class are complex, but they can be simplified somewhat with several broad generalizations.

Regardless of flight rules, the most stringent requirements normally are associated with flight in airspace immediately surrounding a major airport, due to the high density of operations conducted there. Observers must be alert for required communication when it appears a search will be conducted within 40 miles of a major airport or within 5 miles of any airport having an operating control tower. These are color coded *blue* on sectional charts. Major airports in this context are generally near major metropolitan areas and appear at or near the center of concentric blue-, magenta-, or gray-colored circles. Also, crew resource management and the "sterile cockpit" environment are essential in or near these busy airports in order to "see and avoid" obstacles and other aircraft.

When operating the aircraft under VFR, in most classes of airspace the pilot can change the direction of flight or aircraft altitude without any prior coordination with air traffic control. This will almost always be the case when weather allows visual search patterns below the bases of the clouds.

8.4.1 Special Use Airspace

Although not a class of airspace, the FAA has designated some airspace as "special use" airspace. The FAA has specifically created special use airspace for use by the military, although the FAA retains control. Active special use airspace can become a navigational obstacle to search aircraft and uncontrolled objects (e.g., missiles) within the airspace can present a serious threat to the safety of

CAP aircraft and personnel. Special use airspace normally appears on sectional charts as irregularly shaped areas outlined by *either blue or magenta hatched lines*. It is also identified by either a name, such as Tyndall E MOA, or an alphanumerical identifier like R-4404A.

Prohibited Areas contain airspace within which the flight of aircraft is prohibited for national security or other reasons. An example is the airspace around the White House.

In the first example, the letters MOA (Military Operations Area) indicate that the Tyndall E airspace is a military operating area. Within its boundaries, the military may be conducting high-speed jet combat training or practicing air-to-ground weapons attack, without objects actually being released from the aircraft. Figure 8-2 illustrates how the MOA is portrayed on the sectional chart. MOA boundaries and their names are always printed in *magenta* on the sectional chart.

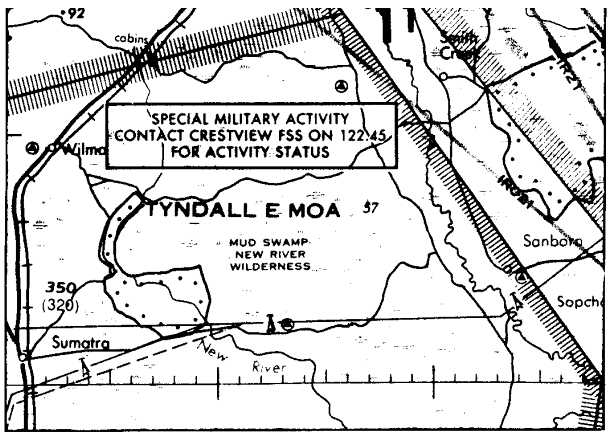

Figure 8-2

Civilian aircraft operating under VFR are *not* prohibited from entering an active MOA, and may do so at any time without any coordination whatsoever (although this is considered foolish by many pilots). As stated earlier, since the FAA retains control of the airspace, it is prudent to contact the controlling air traffic facility before continuing a search into any MOA.

Military aircraft, often flying at very low altitudes and at high speeds, are usually not in radar or radio contact with the air traffic controller (nor can they see or hear you). A controller can only provide positive separation to civilian IFR aircraft from the MOA boundary, *not* from the military aircraft itself. This may force significant maneuvering off your intended course.

In the second example, the “R” prefix to the five-letter identifier indicates this is a *Restricted Area*. The Army may be conducting artillery firing within this airspace, or military aircraft may be practicing actual air-to-surface bombing, gunnery, or munitions testing. Shells, bombs, and bullets, as well as the dirt and fragments they throw into the air on ground impact, present a severe hazard to any aircraft that might come in their path. Figure 8-3 illustrates how a typical restricted area is portrayed on the sectional chart. The restricted area’s boundaries are always printed in *blue*.

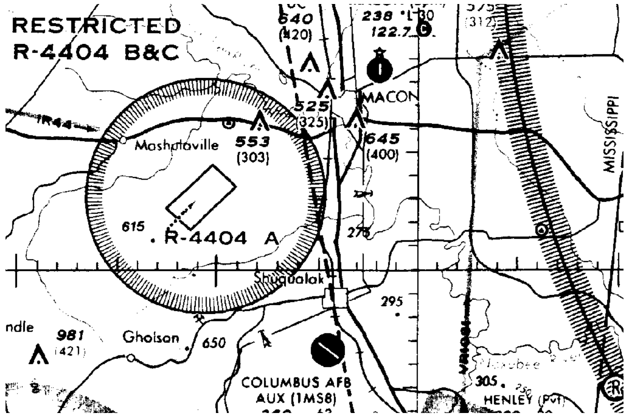

Figure 8-3

Warning Areas are similar to restricted areas, except that they are beyond the three-mile limit from the U.S. coastline and are therefore in international airspace. Alert Areas show airspace within which there may be a lot of pilot training or unusual aerial activity.

Hours of use and vertical limits of special use airspace areas, as well as the FAA facility controlling each area, are printed in one of the margins of the sectional chart. If the CAP crew has any doubt about entering special use airspace, it should contact the appropriate air traffic control facility first to check the status of the area in question.

8.4.2 Military Training Routes

Although not classified by the FAA as special use airspace, military training routes (MTRs) are for military low-altitude high-speed training. An understanding of each type of training route, and the manner in which an active route can affect other traffic, will help the CAP aircrew accomplish their intended mission.

Military training routes that may be used by high-speed jet aircraft are identified by one of two designations, depending upon the flight rules under which the military operates when working within that airspace. *Instrument Routes* (IR) and *Visual Routes* (VR) are identified on sectional aeronautical charts by medium-weight solid gray lines with an alphanumeric designation. 4-digit numbers identify MTRs flown at or below 1500 feet AGL; 3-digit numbers identify those flown above 1500 feet AGL. In Figure 8-4 there are two such examples east of the Clarksville Airport symbol -- IR-120, and VR-1102.

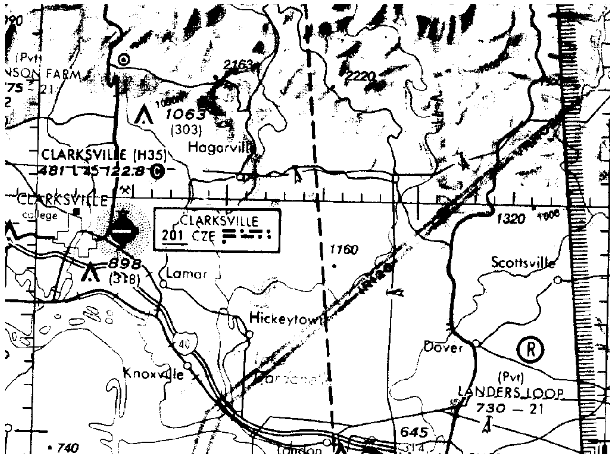

Figure 8-4

Only route centerlines are printed on sectional charts, but each route includes a specified lateral distance to either side of the printed centerline and a specific altitude “block”. Route widths vary, but can be determined for any individual route by requesting Department of Defense *Flight Information Publication AP-1B* at the Flight Service Station.

The letters *IR* in IR-120 indicate that military aircraft operate in that route according to IFR clearances issued by air traffic control. Other non-military VFR aircraft may enter the lateral or vertical boundaries of an active IR route without prior coordination, while aircraft operating IFR are kept out by air traffic control. Just as in the case of a MOA, air traffic control may not have radar and radio contact with the military aircraft using the route. Therefore, it is necessary to provide separation between other IFR aircraft and the route airspace regardless of where the military aircraft may be located along the route. This may force either a route or altitude change. Civil Air Patrol members can request the status of IR routes from the controlling air traffic facility.

The letters *VR* in VR-1102 indicate that the military operates under VFR when operating within the lateral and vertical limits of that airspace. The see-and-avoid concept applies to *all* civilian and military aircraft operating there, and all crew members must be vigilant in visual lookout when within or near a VR training route. Many military missions go to and from visual training routes' start and exit points on IFR clearances, and the prudent crew can inquire about the status of the route with air traffic control when operating through or near a VR training route.

You can determine *scheduled* military activity for restricted areas, MOAs, and military training routes by checking *Notices to Airmen* (NOTAMS) at the Flight Service Station. However, checking with the air traffic control facilities is preferable, since it will reveal *actual,* "real time" activity versus *scheduled* activity. When flying through any special use airspace or training route, crewmembers should be alert and cautious at all times, because incorrect or incomplete coordination between the military and the FAA is the rule rather than the exception.

8.5 Electronic Aids to Navigation (Navaids)

From the standpoint of a mission aircrew, navigational instruments are the means to an end. Navigational equipment allows the aircraft to be flown to a desired location, such as a search pattern entry point, with precision and economy. Once in the search or assessment area, this equipment allows the pilot to fly the assigned area precisely and thoroughly. From the mission staff's viewpoint, proper use of this equipment assures them that the assigned area was actually flown -- the only variables left to accommodate are search effectiveness and the inherent limitations of scanning.

This section will cover some of the electronic means available that can help in navigating. These systems not only can help you determine your position in reduced visibility or over desolate terrain, but can help you more accurately fly search and assessment patterns and report your observations to ground personnel or to mission base.

One drawback to all of this sophisticated equipment is that they may distract the pilot (and observer) from looking outside of the aircraft. The great majority of CAP missions are performed in VFR conditions, and the CAP aircrew must not forget the importance of looking where you're going. The best way to avoid this trap is to become and continue to be very familiar with the operation of this equipment. Training and practice (along with checklists or aids) allows each crewmember to set or adjust instruments with minimum fuss and bother, thus allowing them to return their gaze outside the aircraft where it belongs. All members of the aircrew should be continuously aware of this trap.

Additionally, it is important that observers use this equipment to help the pilot maintain situational awareness. The observer should always know the aircraft's position on the sectional chart, and these instruments enable him or her to do so with great accuracy.

8.5.1 Automatic Direction Finder (ADF)

The automatic radio compass, generally known as the Automatic Direction Finder (ADF), is used to receive radio guidance from stations such as four-course ranges, radio beacons, and commercial broadcast facilities. The automatic direction finder indicates the direction of the station being received. This direction is shown in relation to the heading of the aircraft. The ADF is the least accurate of all the navigational instruments.

Probably the most common use of the automatic direction finder is in “homing”. The pilot tunes in a desired station, and then flies directly to that station by keeping the ADF indicating needle on the zero mark. When the needle points to the zero mark, the aircraft is headed toward the station. When the station is passed, the needle will swing around to the 180-degree position, indicating that the station is behind.

The ADF has three primary components -- a transmitter on the ground, a receiver and an indicator, both in the aircraft. Transmitters include non-directional radio beacons (NDBs) and commercial AM radio stations. Each transmitter emits a single signal on a specific frequency in all directions. ADF equipment aboard the aircraft indicates the *relative* bearing of the station, or its relative direction from the aircraft. In Figure 8-5, the airplane is shown flying north, or flying both a heading and a course of 000°. The ADF "indicator" illustrated shows the direction to the transmitter is 30° to the right of the plane's nose. In the illustration only 0, 090, 180, and 270 are shown on the indicator, and that is true of many ADF indicators. You may have to interpret index marks between these major bearings to determine the exact bearing to the station.

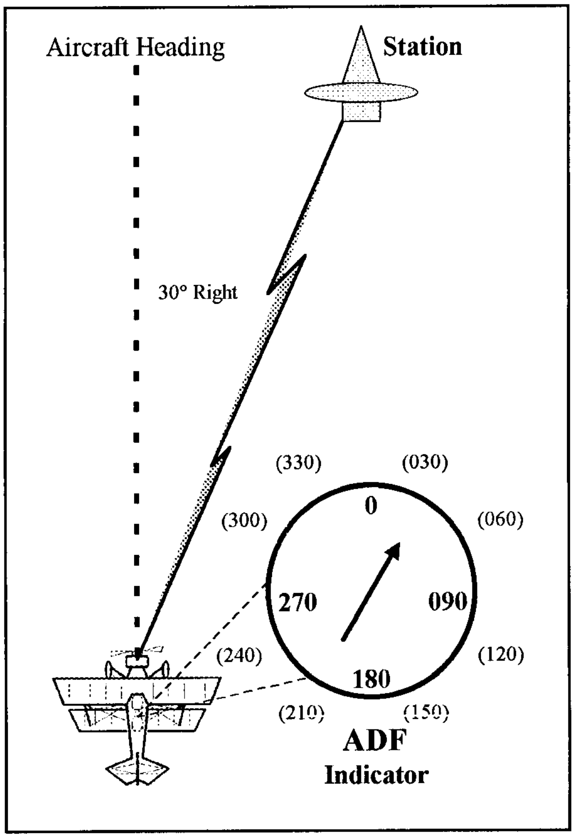

Figure 8-5

If you turn the aircraft 30° to the right (heading 030), the plane will point directly at the station, and the pointer will now point at 0° relative bearing. In a no-wind condition, if you maintained that 030 heading and the pointer at 0° relative bearing, you would fly directly to that transmitter (Figure 8-6).

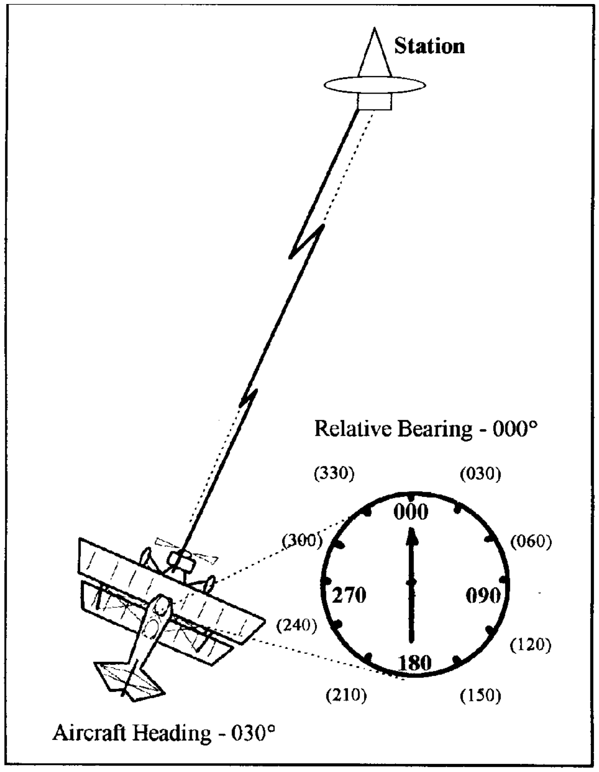

Figure 8-6

In a crosswind, the pilot estimates the airplane's drift, and computes a drift correction factor to be added to or subtracted from the aircraft heading. If he estimates 5° of drift to the right, his drift correction will be to subtract 5° from the airplane's heading, and turn the aircraft 5° to the left. The aircraft would thus have a heading of 025, its course over the ground would remain 030, and the ADF would show a relative bearing of 005, or 5° to the right. In the rowboat-crossing-the-river analogy, the boat's bow points upstream, but due to the current, it travels in a straight line across the river. The aim point is slightly to the right of the bow as the boat proceeds across.

All ADF stations transmit an audible identifier that you must identify before using the signal for navigation. All ADFs are highly susceptible to interference when thunderstorms are in the general vicinity, and their transmissions are restricted to line-of-sight only. Signals can also be blocked by terrain or other obstructions, especially when the aircraft is operating at low altitudes.

8.5.2 Very High Frequency Omnidirectional Range (VOR)

The very high frequency omnidirectional range (VOR) radio navigation system operates on a specific frequency in the VHF range of 109.0 to 117.9 megahertz and transmits 360 directional radio beams or *radials* that, if visible, would resemble the spokes radiating from the hub of a bicycle wheel. Each station is aligned to magnetic north so that the 000 radial points from the station to magnetic north. Every other radial is identified by the magnetic direction to which it points *from* the station, allowing the pilot to navigate directly to or from the station by tracking along the proper radial. The VOR is an accurate and reliable navigational system, and is the current basis for all instrument flight in the U.S.

Like the ADF, the main components are in three pieces: the ground transmitter, the receiver, and the indicator. Controls on the receiver are covered in the Nav/Comm section of Aircraft Instruments.

To help light plane pilots plan and chose routings, the FAA has developed the Victor airway system, a "highway" system in the sky that uses specific courses to and from selected VORs. When tracing the route of a missing aircraft, search airplanes may initially fly the same route as the missing plane, so it is very important you know the proper procedures for tracking VOR radials.

Figure 8-7 shows a VOR indicator and the components that give the information needed to navigate, including a vertical pointer, OFF/TO-FROM flag or window, and a course-select knob. The vertical pointer, also called a course deviation indicator (CDI) is a vertically mounted needle that swings left or right showing the airplane's location in relation to the course selected beneath the course pointer. The OFF/TO-FROM indicator shows whether the course selected will take the airplane to or from the station. When it shows "OFF", the receiver is either not turned on or it's not receiving signals on the selected frequency. The course selector knob is used to select the desired course to fly either toward or away from the station.

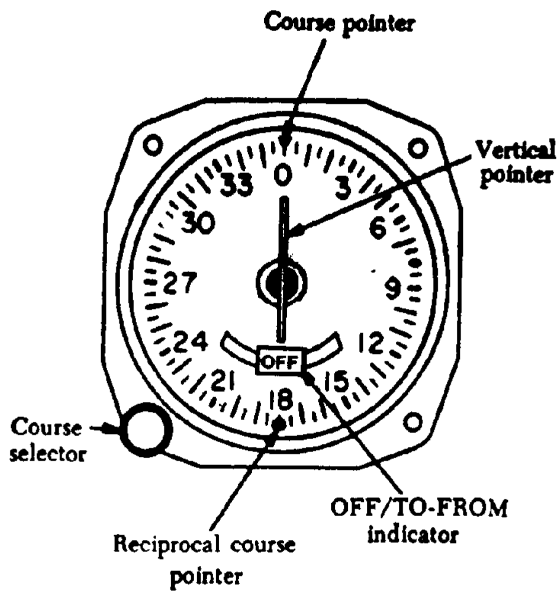

Figure 8-7

Flying to the VOR station is simple. Find the station's frequency and its Morse code audio identifier using the sectional chart. Next, tune the receiver to the correct frequency and identify the station by listening to its Morse code. If you can't positively identify the station, you should not use it for navigation.

After identifying the station, slowly turn the course selector knob until the TO-FROM indicator shows TO and the CDI needle is centered. If you look at the course that's selected beneath the course pointer at the top of the indicator, you'll see the course that will take you directly to the station. The pilot turns the aircraft to match the airplane's heading with that course and corrects for any known winds by adding or subtracting a drift correction factor. The pilot keeps the CDI centered by using very small heading corrections and flies the aircraft directly to the station. When the aircraft passes over the station, the TO-FROM indicator will flip from TO to FROM.

To fly away from a station, tune and identify the VOR, then slowly rotate the course select knob until the CDI is centered with a FROM indication in the window. Look at the selected course, again normally at the top of the indicator, to determine the outbound course. The pilot turns the aircraft to that heading, corrects for wind drift, and keeps the CDI needle in the center to fly directly away from the station.

Figure 8-8 shows a hypothetical VOR with the 0° inbound and outbound courses simulating a Victor airway. In order to fly that airway, set 0° beneath the course pointer and determine the aircraft's position relative to the selected course. Each airplane has the 0° course selected under its course pointer, but the top airplane has a "FROM" indication. This indicates that the plane is north of the station. The vertical pointer's right deflection indicates that the desired 0° course from the station is off to the right. Since the plane is flying about a 330° heading, the pilot would turn back to the right to join the 0° course outbound from the station.

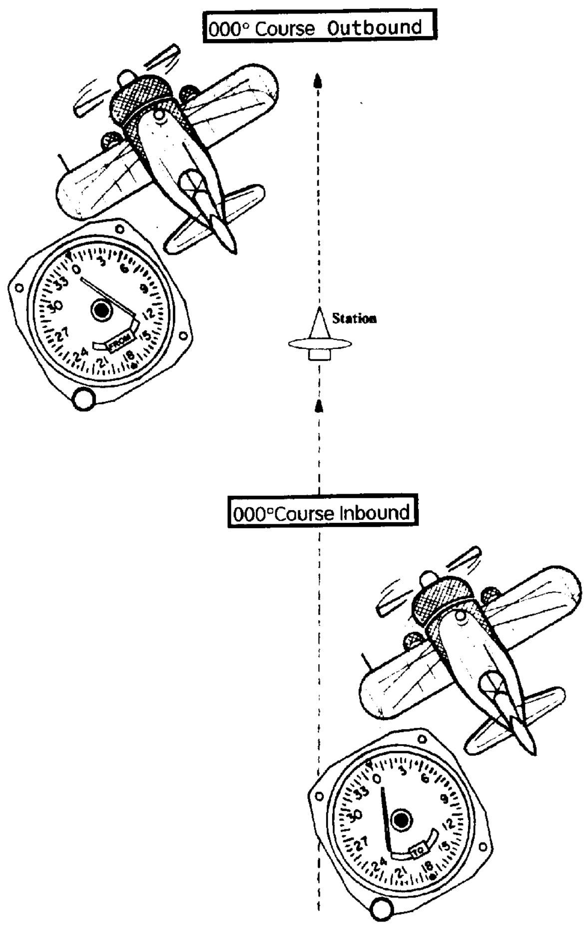

Figure 8-8

The indicator in the airplane southeast of the station has a "TO" indication, which, with the 0° course selected indicates it's south of the station. The pointer's left deflection indicates the 0° course to the station is to the plane's left. Since this plane also is heading 330°, it does not need to turn farther to *intercept* the 0° course to the station.

The display in the north plane would show the same indication if it were heading 360° or 030°, since in any case the 0° course from the station is still to the right. Likewise, the south plane would have the same indications regardless of the direction it's pointed. At any given point in space, the VOR display always gives the same indication *regardless* of the direction the airplane is pointing.

VOR can be used like ADF to determine a position in relation to a selected station, and the process is considerably simpler due to the directional nature of the VOR's signals. Rotate the course select knob slowly until the CDI is centered with a FROM indication, and look beneath the reciprocal course pointer for the radial. You can draw that radial as a line of position from the station's symbol on the sectional chart.

Each VOR station on the chart has a surrounding compass ring already oriented towards magnetic north. Therefore, it isn't necessary to correct for magnetic variation. The use of the printed compass circle surrounding the station on the chart eliminates the need for using the plotter's protractor as well. Use any straight edge to draw the radial by connecting the station symbol with a pencil line through the appropriate radial along the circle. The radial drawn on the chart shows direction, but does not indicate distance from the station. But, you can get an accurate position "fix" by repeating the procedure with another VOR.

Using VOR has several advantages over using ADF. The directional nature of the VOR transmissions makes them easier to use for navigation than the non-directional signal from a NDB. Signals from VOR's are also much less susceptible to interference from thunderstorms and static electricity produced by weather phenomena. The directional signals from VOR's also make it much easier to correct for crosswinds. Like ADF, VOR is limited by signal blockage from high terrain and obstructions or during flight at very low altitudes. Finally, if the VOR equipment has failed you will know it.

In order to use a VOR for instrument flight, the receiver must be functionally checked every thirty days (or prior to any instrument flight). This check must be performed by an instrument rated pilot and logged in the aircraft's flight logbook.

8.5.3 Distance Measuring Equipment (DME)

Finding bearing or direction to a station solves only one piece of the navigation puzzle. Knowing the distance to the station is the final piece to the puzzle that allows fliers to navigate more precisely. You can use crossing position lines from two radio stations to obtain your distance from the stations, but an easier method is provided by distance measuring equipment (DME).

DME continuously measures the distance of the aircraft from a DME ground unit that is usually co-located with the VOR transmitter (then called a VORTAC). The system consists of a ground-based receiver/transmitter combination called a transponder, and an airborne component called an interrogator. The interrogator emits a pulse or signal, which is received by the ground-based transponder. The transponder then transmits a reply signal to the interrogator. The aircraft's DME equipment measures the elapsed time between the transmission of the interrogator's signal and the reception of the transponder's reply and converts that time measurement into a distance.

This measurement is the actual, straight-line distance from the ground unit to the aircraft, and is called *slant range* (Figure 8-9). This distance is continuously displayed, typically in miles and tenths of miles, on a dial or digital indicator on the instrument panel. When DME is used in combination with VOR, a pilot can tell at a glance the direction and distance to a tuned station.

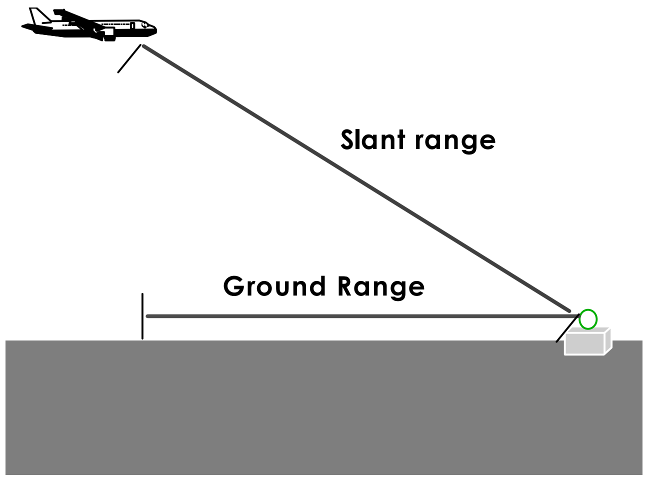

Figure 8-9

DME measures straight-line distance, or slant range, so *there is always an altitude component within the displayed distance*. If you fly toward a station at an altitude of 6,000 feet over the station elevation, the DME will never read zero. It will continuously decrease until it stops at one mile. That mile represents the aircraft's altitude above the station. The distance readout will then begin to increase on the other side of the station. Under most circumstances the altitude component of slant range can be ignored, but when reporting position using DME, especially to air traffic controllers, it is customary to report distances in "DME", not nautical miles, e.g., "Holly Springs 099° radial at 76 DME."

Some DME equipment can also compute and display the actual ground speed of the aircraft, provided that the aircraft is flying *directly* to or from the ground station. In all other circumstances, the ground speed information is not accurate and should be ignored.

8.5.4 LORAN

Long Range Navigation (LORAN) is a navigational system developed by the maritime community that utilizes low frequency radio stations to determine the aircraft position with, under most conditions, considerably greater accuracy than ADF, VOR, or DME. It operates in the 90 to 110 kHz frequency band and is based upon measurement of the difference in time of arrival of radio frequency energy pulses. These pulses are radiated by a chain of transmitters that are separated by hundreds of miles. Within a chain, one station is designated as the master station (M), and the other stations are designated as secondary stations. Signals transmitted from the secondary stations are synchronized with those from the master station. The measurement of a time difference (TD) is made by a receiver that compares a zero crossing of a specified radio-frequency cycle within the pulses received from the master and secondary stations of a chain. Loran provides predictable accuracy of 0.25 nautical miles or better, depending on the user's location within the signal coverage area in certain coastal regions of the chain.

LORAN systems, while having great utility, are vulnerable to certain system problems that can degrade their performance. Because the transmitters are ground-based, high terrain or obstructions between the transmitters and the receiver can block the signal. Ground interference can similarly affect signal reception at very low altitudes even over flat terrain, depending upon the receiver's distance from the chain stations. Signals are also vulnerable to interference from severe electrical storms. Frequently, when the receiver momentarily loses one or more of the stations, the displayed position stays at the last position prior to the signal loss. When the lost signal is acquired again, the calculations resume and the correct position will return. In the interim, however, the "stuck" position is not updating and can give the crew an erroneous indication. Crewmembers are also cautioned to check the instructions of the individual LORAN for the stored chain data. Ground station frequencies and time-delay intervals used within the chains in many cases cannot be “tuned” by the crew, having been permanently programmed by the manufacturer instead.

The FAA has not approved all LORAN receivers for use in instrument flight conditions. A small placard or label on the aircraft instrument panel will list the conditions for use. Unless you are *certain* the receiver and its installation are approved for operations in instrument conditions, LORAN should only be used in visual weather conditions.

LORAN has been replaced on most CAP aircraft by GPS.

8.5.5 Global Positioning System (GPS)

Initially developed by the Department of Defense for military users, the Global Positioning System has become the most accurate navigational system available to civilian aircraft operators. Certified systems will eventually replace many of the navigational systems already discussed, as they already have replaced the ADF. *CAP GPS receivers are not certified for instrument flight, and are thus to be used only for VFR purposes*.

The system relies on a chain of 24 satellite transmitters in polar orbits about the earth. The speed and direction of each satellite, as well as each satellite's altitude is precisely maintained so that each satellite remains in a highly accurate and predictable path over the earth's surface at all times.

GPS receivers process signals transmitted by these satellites and triangulate the receiver's position, which the user again can read directly in latitude and longitude coordinates from a digital display. Similar additional features as those discussed in LORAN are available and vary depending upon the design and manufacturer. The system is substantially more accurate than LORAN, VOR, DME, or ADF and has several advantages.

Because the transmitters are satellite based, not ground based, and the signals are essentially transmitted *downward,* system accuracy is not significantly degraded in mountainous terrain. Additionally, the system is not normally vulnerable to interference from weather or electrical storms. Receivers can typically process as many as twelve received signals simultaneously, and can automatically deselect any satellite whose signal doesn't meet specific reception parameters. The system can function with reasonable accuracy using as few as three received signals.

To a new operator, the GPS is complex and can initially increase the user's workload. Pilots and observers *must read the operating manual or instructions* and become thoroughly familiar with GPS operation before flight, so that operating the GPS *will not become a distraction* from more important tasks. Also, many manufacturers have CD simulators (e.g., U.S. Aviation Technologies' Apollo GX55; www.upsat.com) that allow individuals to practice use of the GPS on a computer.

CAP is standardizing the fleet with the Apollo GX55 (Figure 8-10). Even if your aircraft has a different GPS, the basic functions are the same.

Figure 8-10

All GPS units typically display bearing and distance to a waypoint, altitude, ground speed, estimated time to the waypoint (ETE), and ground track. GPS databases also contain extensive information about a selected waypoint (e.g., an airport) such as runway length and alignment, lighting, approaches, frequencies, and even FBO details such as the availability of 100LL fuel and hours of operation.

The GPS receiver allows the pilot to:

<u>Fly directly to any position</u>

The ability to fly directly to any position (e.g., an airport, navaid, intersection, or user waypoint) saves time and fuel. This reduces transit time, thus allowing more of the crew's allowed duty day to be spent in the search area.

Any of these positions can be entered as the destination through a simple procedure. Additionally, all GPS have a "Nearest Airport" and "Nearest VOR" function, where you can easily display a list of the nearest airports or VORs and then select it as your destination. Positions can also be grouped into flight plans.

Once the destination is entered into the GPS, the heading and the ground track can be monitored. *By matching the heading and ground track (or keeping the CDI centered), you are automatically compensating for wind and thus flying the shortest possible route to your destination*. The GX55 has a Moving Map feature that simplifies this task.

<u>Fly between any two points</u>

The ability to fly directly between any two points greatly improves search effectiveness. These points, usually defined by latitude and longitude (lat/long), can be flown in either of two ways:

- The points can be entered into the GPS as user-defined waypoints. The waypoints can then be recalled in the same manner as you would display an airport or navaid, or they can be entered into a flight plan.
- The pilot can fly between the points by observing the current lat/long display (i.e., a real-time readout of latitude and longitude).

Two factors have reduced search effectiveness in the past: drifting off course due to shifts in wind direction, and drifting off course because of the lack of adequate boundaries (e.g., cross-radials or visible landmarks). Now any search pattern can be flown precisely without relying on cross-radials or ground references. The crew and the mission staff know that a route or area has been covered thoroughly. Also, GPS allows the crew to remain within assigned boundaries, which greatly improves safety when more than one aircraft is in the search area at the same time.

The Apollo GX55 has a "moving map," which greatly enhances situational awareness. It shows aeronautical and ground features in (scalable) detail, and also displays special use airspace. Another feature, added to the unit for CAP use, is the SAR MAP mode. This feature allows you to select, define and fly directly to a CAP grid, and to superimpose a search pattern on the grid (e.g., parallel, creeping line or expanding square). See Chapter 11 and Attachment 2.

8.6 Sectional Charts

The most important tool you will use in both mission flight planning and execution is the chart. Although the earth is spherical, not flat, cartographers can portray small portions of the earth's surface as though it is a flat surface, without affecting accurate navigation. Visual air navigation charts must have certain basic features including:

- Navigational reference system superimposed over the terrain depiction.
- Identifiable, measurable scale to measure distances.
- Detailed graphic depiction of terrain and culture, or man-made features.

Highway road maps are usually not acceptable for air navigation, since most don't have detailed terrain depiction and also lack the superimposed reference system. Many aeronautical charts have such small scales that the makers are unable to show required levels of detail when trying to put a large area into a small chart space. The most useful chart that has been widely accepted for visual, low-altitude navigation is the *sectional aeronautical chart,* sometimes simply referred to as the *"sectional".*

Sectionals use a scale of one to five hundred thousand, or 1:500,000, where all features are shown 1/500,000 of their actual size (1 inch = 6.86 nm). This allows accurate depiction of both natural and cultural features without significant clutter.

Sectionals portray the following:

- Physical, natural features of the land, including terrain contours or lines of equal elevation.
- Man-made or cultural development, like cities, towns, towers, and racetracks.
- Visual and radio aids to navigation, airways, and special-use airspace.
- Airports and airport data, lines of magnetic variation, controlled airspace, obstructions and other important information.
- VFR waypoints.
- Obstructions to flight.

An often overlooked but vital part of the sectional (or any other chart) is the 'Legend.' This is a written explanation of symbols, projections, and other features used on the chart. Figure 8-11 illustrates a portion of the St. Louis sectional chart legend. Other important areas of the sectional chart are its title page or "panel", and the margins around the chart edges. The margins contain supplemental radio frequency information, details about military or *special use airspace,* and other applicable regulations. The title panel identifies the region of the country shown by the chart, indicates the scale used in drawing the chart, explains elevations and contour shading, and shows the expiration date of the chart and effective date of the next issue of that chart. Expired charts should not be used on missions because information on the charts may no longer be correct.

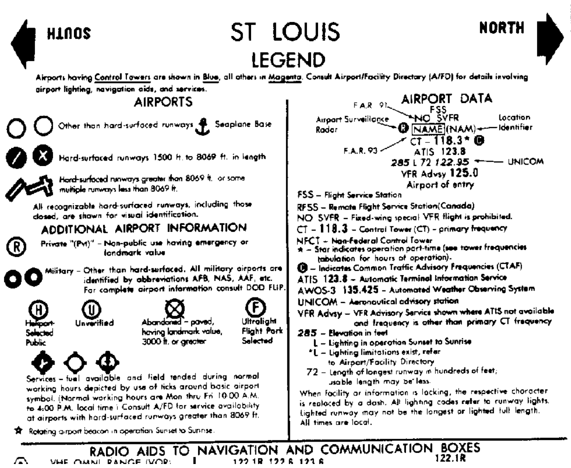

Figure 8-11

Another chart commonly used by VFR pilots is the VFR Terminal Area Charts. The scale of a VFR Terminal Area Chart is 1:250,000 (1 inch = 3.43 nm). The information found on these charts is similar to that found on sectional charts, but the larger scale provides more detail and allows more precise navigation in busy airspace (e.g., Dallas/Ft. Worth Class B airspace).

Both the Sectional and VFR Terminal Area Charts are revised semi-annually. *It is vitally important that you keep current charts in the aircraft at all times*. Obsolete charts should be discarded and replaced by new editions. To make certain that your sectionals are up-to-date, you can refer to the National Ocean Survey (NOS) Aeronautical Chart Bulletin in the Airport/Facility Directory. This bulletin provides the VFR pilot with the essential information necessary to update and maintain current charts. It lists the major changes in aeronautical information that have occurred since the last publication date of each chart, such as:

- Changes to airports, controlled airspace and radio frequencies.
- Temporary or permanent closing of runways or navigational aids.
- Changes special use airspace that present hazardous conditions or impose restrictions on the pilot.

8.7 Chart Interpretation

A significant part of air navigation involves interpreting what one sees on the chart, then making comparisons outside the aircraft. It is most important that observers be thoroughly acquainted with the chart symbols explained in the chart legend, and the relief information discussed on the chart's title panel.

Basic chart symbols can be grouped into cultural features, drainage features, and relief features. Understanding cultural features is straightforward, and they usually require little explanation. Villages, towns, cities, railroads, highways, airports or landing strips, power transmission lines, towers, mines, and wells are all examples of cultural features. The chart legend explains the symbols used for most cultural features, but if no standard symbol exists for a feature of navigational significance, the cartographer frequently resorts to printing the name of the feature itself, such as *factory* or *prison,* on the chart.

Drainage features on charts include lakes, streams, canals, swamps, and other bodies of water. On sectional charts these features are represented by lightweight solid blue lines for rivers and streams; large areas of water, such as lakes and reservoirs, are shaded light blue with the edges defined by lightweight solid blue lines. Under most conditions, the drainage features on a map closely resemble the actual bodies of water. However, certain bodies of water may change shape with the season, or after heavy rains or drought. Where this shape change occurs with predictability, cartographers frequently illustrate the maximum size expected for a body of water with light-weight, blue, dashed lines. If you intend to use drainage features for navigation, you should consider recent rains or dry spells while planning and remember the body of water may not appear exactly as depicted on the chart.

8.7.1 Relief

Relief features indicate vertical topography of the land including mountains, valleys, hills, plains, and plateaus. Common methods of depicting relief features are contour lines, shading, color gradient tints, and spot elevations. Contour lines are the most common method of depicting vertical relief on charts. The lines do not represent topographical features themselves, but through careful study and interpretation, you can predict a feature's physical appearance without actually seeing it. Each contour line represents a continuous imaginary line on the ground on which all points have the same elevation above or below sea level, or the zero contours. Actual elevations above sea level of many contour lines are designated by a small break in the line, while others are not labeled. Contour interval, or vertical height between each line, is indicated on the title panel of sectionals.

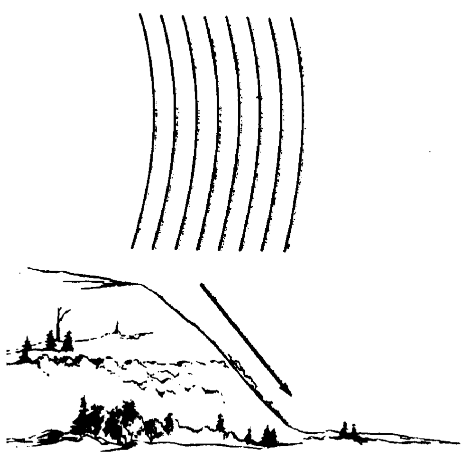

Figure 8-12

Contour lines are most useful in helping us to visualize vertical development of land features. Contour lines that are grouped very closely together, as in Figure 8-12, indicate rapidly changing terrain, such as a cliff or mountain. More widely spaced lines indicate more gentle slopes. Absence of lines indicates flat terrain. Contour lines can also show changes in the slope of terrain. Figures 8-13 and 8-14 show how to predict the appearances of two hillsides based upon their depictions on a chart.

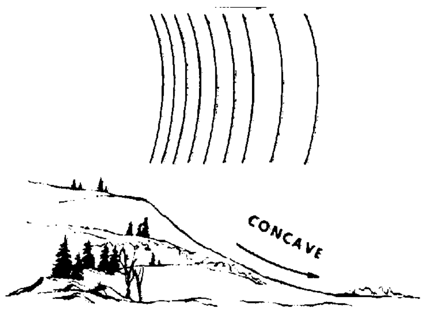

Figure 8-13

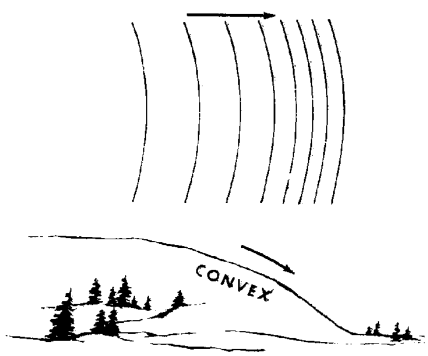

Figure 8-14

Precise portrayal and interpretation of contour lines allows accurate prediction of the appearance of terrain you expect to fly over or near. Figure 8-15 shows the depiction of a saddle in a short ridgeline, and Figure 8-16 shows how it might appear from the aircraft. Many other types of terrain features can be predicted by careful study of contour lines. An outdated chart can be a useful tool for helping to develop your skills, but don't use it in flight.

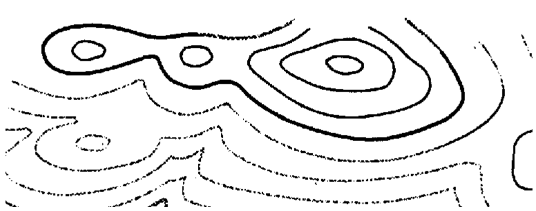

Figure 8-15

Figure 8-16

Shading is added to sectional charts to help highlight and give contrast to the contour lines. These tiny gray dots are applied adjacent to selected contour lines and give the contours a three-dimensional appearance. This makes it easier to imagine the physical appearance of the shaded topographical feature.

Gradient tints, the "background" colors on charts, indicate general areas of elevation. The height range assigned to each gradient color is indicated on the title panel of each sectional chart. Areas that are near sea level are pale green, while *high terrain is color-coded a deep red/brown*. Intermediate elevations are indicated by brighter shades of green, tan, or lighter shades of red/brown.

A spot elevation is the height of a specific charted point. On sectional charts, this height is indicated by a number next to a black dot, the number indicating the height of the terrain above sea level.

8.7.2 Aeronautical Data

The aeronautical information on the sectional charts is for the most part self-explanatory. Information concerning very high frequency (VHF) radio facilities such as tower frequencies, omnidirectional radio ranges (VOR), and other VHF communications frequencies is shown in blue. A narrow band of blue tint is also used to indicate the centerlines of Victor Airways (VOR civil airways between omnirange stations). Low frequency-medium frequency (LF/MF) radio facilities are shown in magenta (purplish shade of red).

In most instances, FAA navigational aids can be identified by callsigns broadcast in International Morse Code. VOR stations and Non-directional Radio Beacons (NDB) use three-letter identifiers that are printed on the chart near the symbol representing the radio facility.

Runway patterns are shown for all airports having permanent hard surfaced runways. These patterns provide for positive identification as landmarks. All recognizable runways, including those that may be closed, are shown to aid in visual identification. Airports and information pertaining to airports having an airport traffic area (operating control tower) are shown in blue. All other airports and information pertaining to these airports are shown in magenta adjacent to the airport symbol that is also in magenta.

The symbol for obstructions is another important feature. The elevation of the top of obstructions above sea level is given in blue figures (without parentheses) adjacent to the obstruction symbol.

Immediately below this set of figures is another set of lighter blue figures (enclosed in parentheses) that represent the height of the top of the obstruction above ground-level. Obstructions which extend less than 1,000 feet above the terrain are shown by one type of symbol and those obstructions that extend 1,000 feet or higher above ground level are indicated by a different symbol (see sectional chart). Specific elevations of certain high points in terrain are shown on charts by dots accompanied by small black figures indicating the number of feet above sea level.

The chart also contains larger bold face blue numbers that denote Maximum Elevation Figures (MEF). These figures are shown in quadrangles bounded by ticked lines of latitude and longitude, and are represented in thousands and hundreds of feet above mean sea level. The MEF is based on information available concerning the highest known feature in each quadrangle, including terrain and obstructions (e.g., trees, towers, and antennas).

Since CAP aircraft regularly fly at or below 1000' AGL, aircrews should exercise extreme caution because of the numerous structures extending up as high as 1000' – 2000' AGL. Additionally, guy wires that are difficult to see even in clear weather support most truss-type structures; these wires can extend approximately 1500 feet horizontally from a structure. Therefore, all truss-type structures should be avoided by at least 2000 feet (horizontally and vertically).

Overhead transmission and utility lines often span approaches to runways and scenic flyways such as lakes, rivers and canyons. The supporting structures of these lines may not always be readily visible and the wires may be virtually invisible under certain conditions. Most of these installations do not meet criteria that determine them to be obstructions to air navigation and therefore, do not require marking and/or lighting. The supporting structures of some overhead transmission lines are equipped with flashing strobe lights, which indicate that wires exist between the strobe-equipped structures. Also, some lines have large orange “balls” spaced along their length.

An explanation for most symbols used on aeronautical charts appears in the margin of the chart. Additional information appears at the bottom of the chart.

8.8 Chart Preparation

Careful chart preparation and route study before the flight can increase your efficiency and decrease your workload during the flight. You should try to develop a systematic approach to chart preparation.

The first step in planning any leg is to locate the departure point and destination on the chart, and lay the edge of a special protractor, or plotter, along a line connecting the two points, as shown in Figure 8-17. Read the true course for this leg by sliding the plotter left or right until the center point, or grommet, sits on top of a line of longitude. When the course is more to the north or south, you can measure it by centering the grommet on a parallel of latitude, then reading the course from the inner scale that’s closer to the grommet.

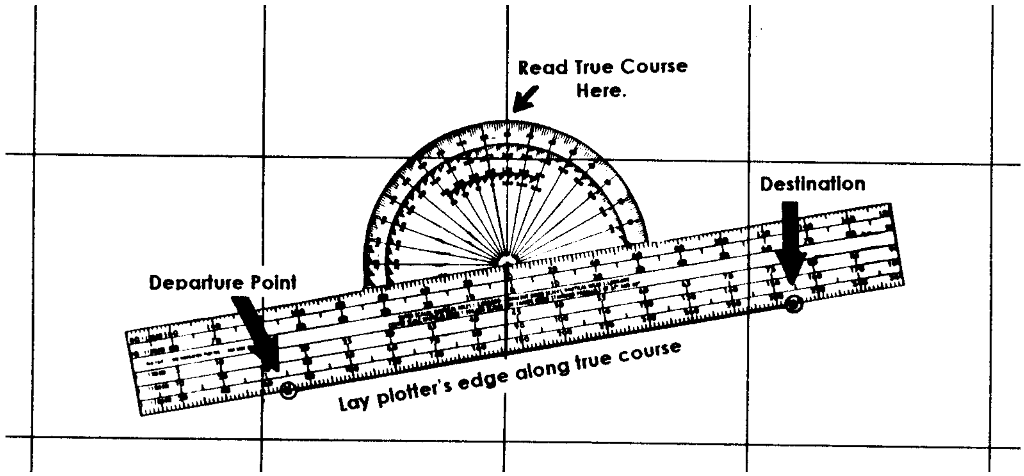

Figure 8-17

The discussion that follows concerns one leg of a flight from University-Oxford airport, near Oxford, Mississippi, to the Ripley airport, near Ripley, Mississippi. The same basic principles used in planning this single leg are used in all air navigation and apply to more complex search patterns.

In Figure 8-18, the chart for this "flight", the two points are connected with a solid line. This line represents the *true* course from Oxford to Ripley and is 051°. If you were interested in going the opposite direction, the course would be the *reciprocal* course, 231°, which also appears on the arc of the plotter. Remain aware of the relationship among general directions -- north, east, south, and west -- and their directions indicated by degrees on the compass -- 000, 090, 180, and 270, respectively. Since almost all charts are printed with north to the top of the chart, you can look at the intended direction of flight, which runs right and up, or to the northeast, and know immediately that 051 is correct and 231 is not.

Notice the broken line that nearly passes through the Oxford airport symbol, and follow it toward the bottom of the page. Near the bottom, you'll see the numbers 1°30' E. This is the magnetic variation correction factor for that area.

If you subtract east variation or add west variation to the true course, you can determine the magnetic course. Most fliers advocate writing the "mag" course right on the chart. Round 1° 30' down to 1° and subtract that from the true course to obtain 050 for the magnetic course. Also notice that Oxford is within the boundaries of the Columbus 3 Military Operating Area (MOA). To avoid an unpleasant encounter with a high-speed jet, you can look at the table in the chart's margin, partially shown in Figure 8-19, and determine that jets using this area do not operate below 8,000 feet. You can note this on the chart with a line over 8,000, which means to remain below 8,000 feet.

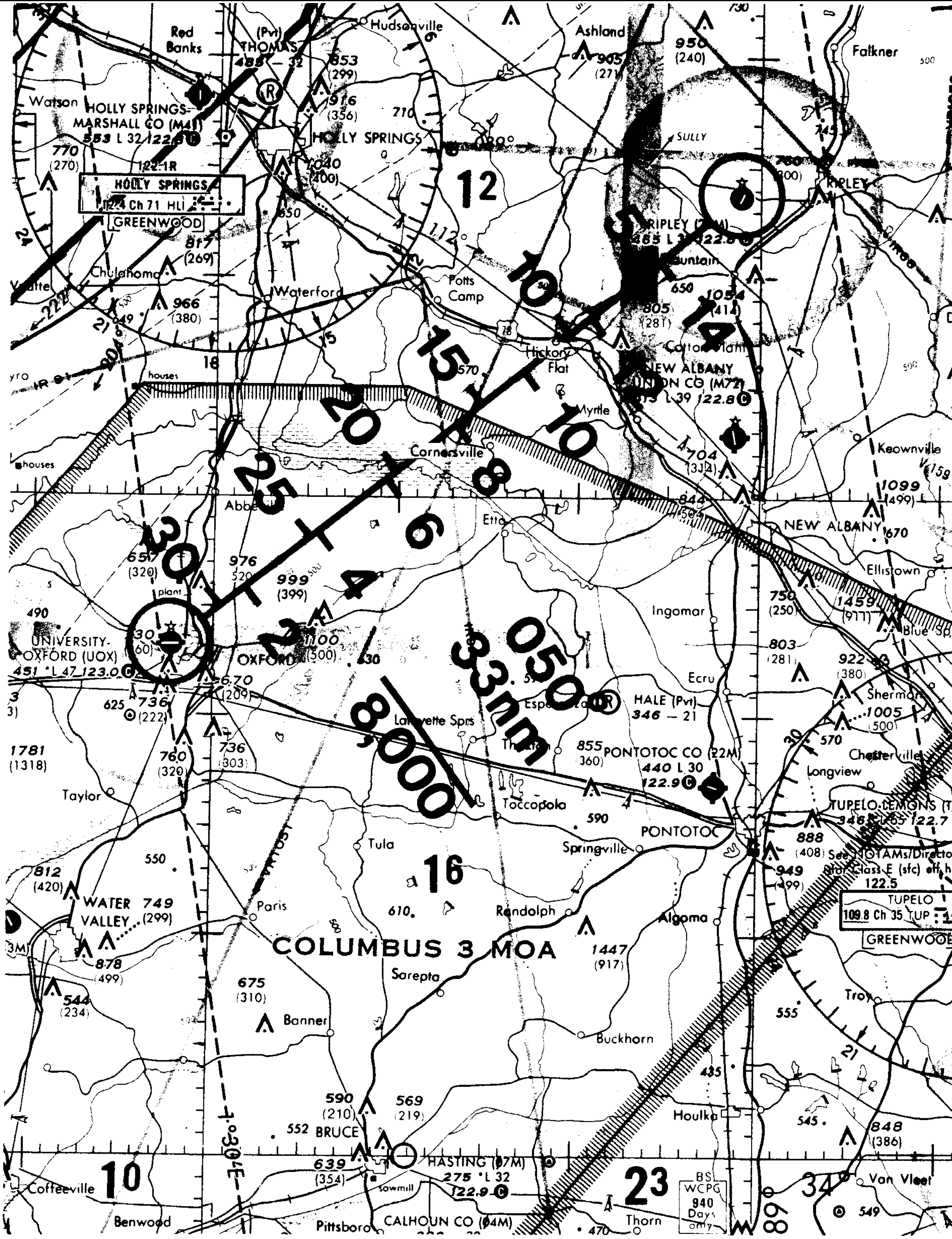
Red Banks
(Pvt) THOMAS
Hudsonville
Ashland
Falkner
Watson
HOLLY SPRINGS-MARSHALL CO (M41)
HOLLY SPRINGS
HOLLY SPRINGS
112.4 Ch 71 HLI
GREENWOOD
12
RIPLEY
RIPLEY (27M)
Chulahoma
Waterford
Potts Camp
Hickory Flat
NEW ALBANY UNION CO (M72)
Myrtle
Cornersville
Keownville
Abbeville
Etta
NEW ALBANY
Ellistown
Ingomar
Blue Spgs
UNIVERSITY-OXFORD (UOX)
OXFORD
Ecru
HALE (Pvt)
Sherman
Lafayette Sprs
Esperanza
Thaxton
PONTOTOC CO (22M)
Chesterville
Longview
Taylor
Toccopola
TUPELO LEMONS
PONTOTOC
Tula
Springville
16
WATER VALLEY
Paris
Randolph
Algoma
TUPELO
109.8 Ch 35 TUP
GREENWOOD
COLUMBUS 3 MOA
Sarepta
Troy
Banner
Buckhorn
Houlka
BRUCE
HASTING (07M)
CALHOUN CO (04M)
Coffeeville
Benwood
Pittsboro
Thorn
Van Vleet
10
23
050
33nm
8,000

Figure 8-18

Next you must determine the total distance you're going to fly. Measure this using the scale that's printed on the plotter's straight edge, making sure you use a scale appropriate to the scale of the chart. Use the 1:500,000 scale for sectionals. As an alternative, lay a paper's edge along the course line, make pencil marks on the paper's edge at the two airports, and then lay that same edge along the line of longitude. By simply counting the minute marks on the chart's longitude line that fall between those two pencil marks, you can determine the distance between the two airports in nautical miles. In the example, Oxford and Ripley are 33 nm, or 33 nautical miles, apart.

There are a number of ways you can add information to your chart that will help during the flight. Each flier has his own techniques or variations of the techniques presented here, and over time, you will develop a preference for methods that work best for you.

Tick marks along the course line at specific intervals will help you keep track of your position during flight. Some individuals prefer 5 or 10 nm intervals for tick marks, while others prefer 2 or 4 nm intervals. Four-nautical mile spacing works well for aircraft that operate at approximately 120 knots. Since the 120-knot airplane travels 2 nm every minute, each 4 nm tick mark represents approximately two minutes of flight time. This will become more significant when you study navigational methods in later paragraphs. On the example chart, you have tick marks on the right side of the course line at 4 nm intervals. If the search airplane has an airspeed indicator marked in miles per hour instead of knots, it may be advantageous to space the tick marks in statute mile intervals.

On the left side of the course line you have more tick marks, at 5 nm intervals, but measured backward from the destination. In flight, these continuously indicate distance remaining to the destination. Later in this chapter you will learn about radio aids to navigation that you can use to continuously confirm remaining distance.

The next step in preparing the chart is to identify "*check points*" along the course; you can use these to check your position on or off course, and the timing along the leg. Prominent features that will be easily seen from the air make the best checkpoints, and many fliers like to circle them or highlight them with a marker in advance. On the example, you might expect to see the large towers east of Oxford about 3 nm to your right shortly after take off, and expect later to see the town of Cornersville. Shortly thereafter, you expect to see the road and railroad bend east of Hickory Flat, followed by the Ripley Airport itself. In the example, the checkpoints are widely spaced, but on actual missions checkpoint spacing will be controlled by the search altitude and weather conditions and visibility at the time of the flight.

MOA NAME	ALTITUDE OF USE	TIME OF USE	CONTROLLING AGENCY
ANNE HIGH	7,000	SR - SS MON - FRI	ZFW CNTR
BIRMINGHAM	10,000	0700-2200	ZTL CNTR
COLUMBUS 1, 2, & 3	8,000	SR - SS MON - FRI	ZME CNTR
MERIDIAN 1 EAST	8,000	SR - SS MON - FRI	ZME CNTR

Altitudes indicate floor of MOA. All MOAs extend to but do not include FL180 unless otherwise indicated in tabulation or on chart.

Other information that may be written on the chart includes estimated times of arrival (ETAs) at each checkpoint and reminders like "check gas", "switch tanks", or "contact mission base". Crewmembers are likely to spend less time "fishing" about the cockpit trying to find information in flight if it is already written on the chart.

8.8.1 Plotting the Course

Lay the chart on a table or other flat surface, and draw a straight line from your point of departure to the destination (airport to airport). This can be done with a plain ruler or, better, with a navigation plotter. Mark off the distance in 10 or 20-mile intervals. Use a sharp pencil, making sure the line is straight and that it intersects the center of the airport symbol. Make a careful study of the intervening country and decide whether to fly direct or whether a detour may be desirable in order to avoid flying over large bodies of water, mountains, or other hazardous terrain. Note whether landing fields are available enroute for refueling or use in case of an emergency. Using an appropriate groundspeed and the actual distance to destination, estimate your time enroute. You should know the range (in fuel hours) of the aircraft you intend to fly. From this you can determine whether or not you can make the flight without fueling stops. Be sure to allow at least a 45-minute reserve fuel supply at your destination or at any intermediate fueling stop.

8.8.2 Checkpoints

Now that you have established a definite course from departure to destination, study the terrain on the chart and choose suitable checkpoints. These can be distinctive patterns: railroad tracks or highways, sharp bends in rivers, racetracks, quarries, and small lakes. As your flight progresses, the checkpoints will be used to maintain the correct course and to estimate the groundspeed. Your checkpoints need not be on your direct line of flight, but should be near enough to be easily seen. For this part of the preflight planning it is essential that you know the chart symbols (explained on the back of the chart) in order to recognize the many landmarks available as checkpoints.

8.8.3 Enclosing the Course

This consists of using an easily recognizable feature on the terrain that lies parallel to your course. It may serve as a guideline or bracket, and may be a river, railroad track, or a prominent highway. The ideal arrangement would be to have a continuous guideline on each side of the route five to 10 miles from the line of flight. It is seldom that two can be found, but one will usually serve satisfactorily. If you should temporarily lose your checkpoints, you can fly to this chosen guideline and reset course. Another landmark should be used as an end-of- course check to prevent flying beyond your destination should you miss it or actually fly directly over it.

8.8.4 True Course

Having plotted your course and made an accurate listing of checkpoints and the distances between them, measure the true course counting clockwise from true north. Use the meridian (north-south) line approximately midway between departure and destination. Your true course can be measured with a common protractor, or better still with a navigation plotter.

When using the GPS, the pilot will be able to easily follow the precise true course between departure point and destination. Without the GPS, magnetic variation, wind and compass deviation would affect the aircraft's ground track.

8.9 Standardized Grid Systems

A grid is a network of regularly spaced horizontal and vertical lines used to help quickly locate points on a map. Most city street maps have grid systems that help motorists locate streets or other points of interest. A commonly used grid system on city street maps involves numerical and alphabetical references. Regularly spaced letters may be printed across the top of such a map designating imaginary vertical columns, while regularly spaced numbers are printed down the sides of the map designating imaginary horizontal rows. If you want to find Maple Street and the map directory indicates Maple Street is located in section K-5, you then look at or near the intersection of column K with row 5. Within that area, you should find Maple Street.

The Civil Air Patrol has found it useful to construct similar grid systems on aeronautical charts for search and rescue operations. Some maps, like city maps, already have grid systems constructed on them, but aeronautical charts typically do not. You can construct a grid system on any type of chart or map. You may use numbers and letters like street maps, or you could use only numbers. In either case, the system should give *every* user a common, standardized method for identifying a location according to its position within the grid. It is very easy to exchange location information over the radio using the grid system. With the known grid positions, other team members can quickly determine on their own charts the location of a sighting or point of interest.

Grid systems are especially helpful when locating a position that has no nearby distinguishable landmarks or features, such as buildings, roads, or lakes. Grid systems will work anywhere, even in the middle of large lakes, in deep woods, or in swamps. Anyone can develop a workable system provided that all members of the search team use the same grid system.

8.9.1 Sectional Chart Grids

The Civil Air Patrol has adopted a standard grid system built upon the matrix of parallels of latitude and meridians of longitude and the sectional aeronautical chart. Sectional charts cover a land area approximately seven degrees of longitude in width and four degrees of latitude in height. Information pertaining to gridding can be found in Attachment E of the *U.S. National SAR Supplement to the International Aeronautical and Maritime SAR Manual* (Attachment 1).

Table 8-1 shows the latitude and longitude boundaries of each sectional chart. The St. Louis chart, for example, covers an area that is bounded by the following latitudes and longitudes: North 40° 00' (north boundary), North 36° 00' (south boundary), West 91°-00' (west boundary), and West 84°-00'(east boundary).

Chart	Identifier	North Grid Limit	South Grid Limit	West Grid Limit	East Grid Limit	Total Grids
Seattle	SEA	49-00N	44-30N	125-00W	117.00W	576
Great Falls	GTF	49-00N	44-30N	117-00W	109-00W	576
Billings	BIL	49-00N	44-30N	109-00W	101-00W	576
Twin Cities	MSP	49-00N	44-30N	101-00W	93-00W	576
Green Bay	GRB	48-15N	44-00N	93-00W	85-00W	544
Lake Huron	LHN	48-00N	44-00N	85-00W	77-00W	512
Montreal	MON	48-00N	44-00N	77-00W	69-00W	512
Halifax	HFX	48-00N	44-00N	69-00W	61-00W	512
Klamath Falls	LMT	44-30N	40-00N	125-00W	117-00W	576
Salt Lake City	SLC	44-30N	40-00N	117-00W	109-00W	576
Cheyenne	CYS	44-30N	40-00N	109-00W	101-00W	576
Omaha	OMA	44-30N	40-00N	101-00W	93-00W	576
Chicago	ORD	44-00N	40-00N	93-00W	85-00W	512
Detroit	DET	44-00N	40-00N	85-00W	77-00W	512
New York	NYC	44-00N	40-00N	77-00W	69-00W	512
San Francisco	SFO	40-00N	36-00N	125-00W	118-00W	448
Las Vegas	LAS	40-00N	35-45N	118-00W	111-00W	476
Denver	DEN	40-00N	35-45N	111-00W	104-00W	476
Wichita	ICT	40-00N	36-00N	104-00W	97-00W	448
Kansas City	MKC	40-00N	36-00N	97-00W	90-00W	448
St. Louis	STL	40-00N	36-00N	91-00W	84-00W	448
Cincinnati	CVG	40-00N	36-00N	85-00W	78-00W	448
Washington	DCA	40-00N	36-00N	79-00W	72-00W	448
Los Angeles	LAX	36-00N	32-00N	121-30W	115-00W	416
Phoenix	PHX	35-45N	31-15N	116-00W	109-00W	504
Albuquerque	ABQ	36-00N	32-00N	109-00W	102-00W	448
Dallas-Fort	DFW	36-00N	32-00N	102-00W	95-00W	448
Worth	MEM	36-00N	32-00N	95-00W	88-00W	448
Memphis	ATL	36-00N	32-00N	88-00W	81-00W	448
Atlanta	CLT	36-00N	32-00N	81-00W	75-00W	384
Charlotte						
El Paso	ELP	32-00N	28-00N	109-00N	103-00W	384
San Antonio	SAT	32-00N	28-00N	103-00W	97-00W	384
Houston	HOU	32-00N	28-00N	97-00W	91-00W	384
New Orleans	MSY	32-00N	28-00N	91-00W	85-00W	384
Jacksonville	JAX	32-00N	28-00N	85-00W	79-00W	384
Brownsville	BRO	28-00N	24-00N	103-00W	97-00W	384
Miami	MIA	28-00N	24-00N	83-00W	77-00W	384

Table 8-1

The sectional grid system used by Civil Air Patrol divides each sectional's area into 448 smaller squares. This process begins by dividing the whole area into 28 *1-degree* grids, using whole degrees of latitude and longitude as shown in Figure 8-19. Then each 1-degree grid is divided into four *30-minute* grids, using the 30-minute latitude and longitude lines as shown in Figure 8-20. Finally, each of the 30-minute grids is divided into four *15-minute* grids, using the 15- and 45-minute latitude and longitude lines as shown in Figure 8-23.

Note: The information on this chart is contained in the GX55 database.

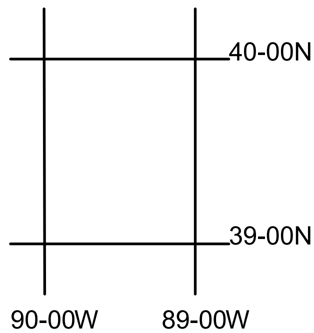

Figure 8-19

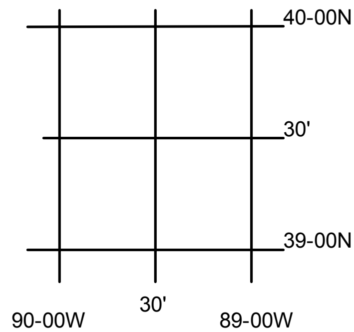

Figure 8-20

Next, the grid squares are numbered 1 through 448 beginning usually with the most northwest square on the entire sectional, and continuing straight east through number 28. The numbering resumes in the second row, with number 29 placed beneath number 1, 30 beneath 2, and so on through 56. The third row begins with number 57 beneath numbers 1 and 29, and continues through 84. Numbering continues through successive rows until all 448 squares have a number.

In Figure 8-21, each 15-minute grid square has the number it would have received if this demonstration had started with the entire St. Louis sectional chart. Table 8-2 represents the division of the whole St. Louis sectional into 15-minute grids, with respective grid numbers assigned. To conserve space Table 8-2 doesn't include the area between longitudes 85° W and 89°30'W.

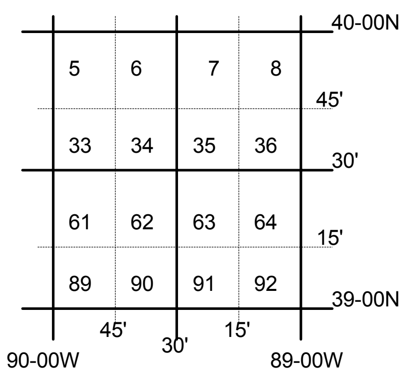

Figure 8-21

40-00N	91-00W					90-00W				85-00W		
	MKC 25	MKC 26	MKC 27	MKC 28	STL 5	STL 6	< >	< >	STL 25	STL 26	STL 27	STL 28
	MKC 53	MKC 54	MKC 55	MKC 56	STL 33	STL 34	< >	< >	STL 53	STL 54	STL 55	STL 56
	MKC 81	MKC 82	MKC 83	MKC 84	STL 61	STL 62	< >	< >	STL 81	STL 82	STL 83	STL 84
39-00N	MKC 109	MKC 110	MKC 111	MKC 112	STL 89	STL 90	< >	< >	STL 109	STL 110	STL 111	STL 112
	MKC 137	MKC 138	MKC 139	MKC 140	STL 117	STL 118	< >	< >	STL 137	STL 138	STL 139	STL 140
	MKC 165	MKC 166	MKC 167	MKC 168	STL 145	STL 146	< >	< >	STL 165	STL 166	STL 167	STL 168
	MKC 193	MKC 194	MKC 195	MKC 196	STL 173	STL 174	< >	< >	STL 193>	STL 194	STL 195	STL 196
38-00N	MKC 221	MKC 222	MKC 223	MKC 224	STL 201	STL 202	< >	< >	STL 221	STL 222	STL 223	STL 224
	MKC 249	MKC 250	MKC 251	MKC 252	STL 229	STL 230	< >	< >	STL 249	STL 250	STL 251	STL 252
	MKC 277	MKC 278	MKC 279	MKC 280	STL 257	STL 258	< >	< >	STL 277	STL 278	STL 279	STL 280
	MKC 305	MKC 306	MKC 307	MKC 308	STL 285	STL 286	< >	< >	STL 305	STL 306	STL 307	STL 308
37-00N	MKC 333	MKC 334	MKC 335	MKC 336	STL 313	STL 314	< >	< >	STL 333	STL 333	STL 334	STL 336

Table 8-2

Returning to Table 8-1, notice that the eastern limit of the Kansas City sectional grid, 90° 00’W, is one full degree of longitude east of the western limit of the St. Louis sectional, 91° 00’ W. The two sectionals overlap by one full degree of longitude. When drawing a grid over this overlap area, which numbers would you assign to these grid squares, the Kansas City or St. Louis grid numbering?

In cases where two sectionals overlap one another, the Civil Air Patrol always uses the numbering system for the western-most chart of the two in question. You can see this in Table 8-2, where the overlap area between 90° 00’ and 91° 00’, shown in the first 4 vertical columns, is identified with Kansas City (MKC) grid numbering, not St. Louis. Note too that, since the Kansas City grid numbering is used in this overlap area, the first 4 columns of the St. Louis grid numbering system are omitted. Several other such overlaps exist within the grid system.

Attachment 2 tells you how many grids are in each sectional. If the table is not available you can compute it using the grid limits. Take the difference in the northern and southern grid limits and multiply by 4 (1/4 degree x 4 to make 1 degree.) Do the same for the east and west grid limits. Then multiply the two products to get the total number of grids on your sectional. For example, the St. Louis sectional extends 4° from 40°-00’ N to 36°-00’ N. Each degree will contain 4 grids, so there will be 4 x 4 = 16 rows of grids. The sectional extends east/west for 7° from 91°-00’ W - 84°-00’ W, so there will be 7 x 4 = 28 columns of grids. Therefore, the total number of grids on the chart is 16 x 28 = 448. Remember some sectionals don't start counting at 1 because of overlap with an adjacent sectional. If your sectional does this you need to memorize the first grid number:

When circumstances require, a 15-minute grid can be divided into 4 more quadrants using 7 1/2 degree increments of latitude and longitude, creating 4 equal size grids that are approximately 7 1/2 miles square. The quadrants are then identified alphabetically - A through D - starting with the northwest quadrant as A, northeast as B, southwest as C and southeast as D, as in Figure 8-22. A search area assignment in the southeast quadrant may be given as "Search STL 5D."

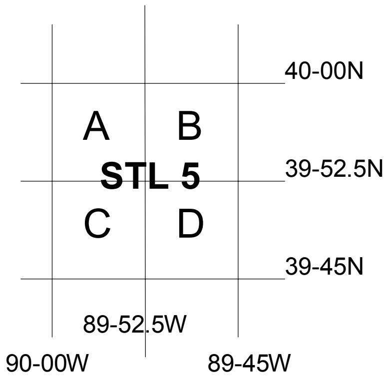

Figure 8-22

Pinpointing an area within the grid system becomes easy once you gain familiarity with the grids' many uses. You soon will be able to quickly plot any area on a map and then fly to it using the basic navigation techniques already discussed.

8.10 Standardized Lat/Long Grid System

Another means of designating a grid system is the Standardized Latitude and Longitude Grid System. It has an advantage over the sectional standardized grid in that it can be used on any kind of chart that has lines of latitude and longitude already marked. In this system, 1-degree blocks are identified by the intersection of whole numbers of latitude and longitude, such as 36-00N and 102-00W. These points are always designated with the latitude first, such as 36/102, and they identify the area north and west of the intersection of these two lines. In Figure 8-23, the gray shading identifies section 36/102.

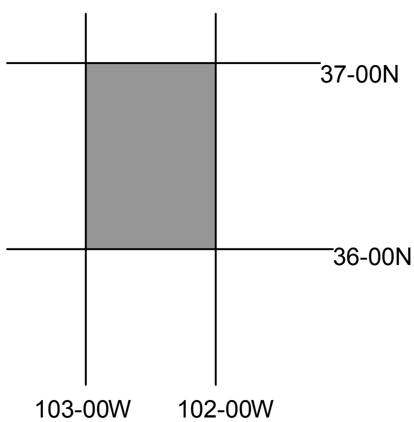

Figure 8-23

Next, the 1-degree grid is divided into 4 quadrants using the 30-minute lines of latitude and longitude. Label each quadrant A through D; the northwest quadrant being 36/102A, the northeast 36/102B, the southwest 36/102C, and the southeast 36/102D as shown in Figure 8-24.

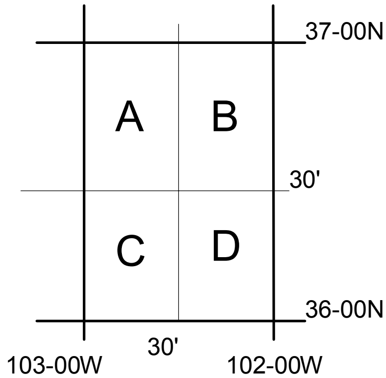

Figure 8-24

Each quadrant can also be divided into 4 sub-quadrants, labeled AA, AB, AC, and AD, again starting with the most northwest and proceeding clockwise, as shown in Figure 8-25. This grid system works on any chart that has latitudes and longitudes printed on it. [Note: The GX-55 can be set to use basic grids measuring 10° by 10°, refer to Attachment 2.]

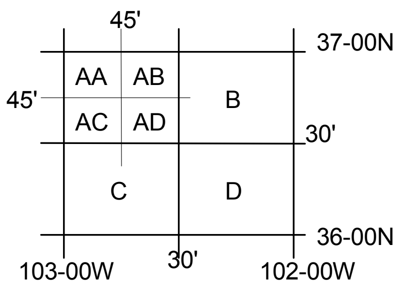

Figure 8-25